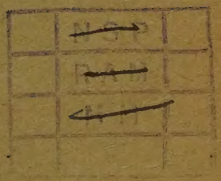
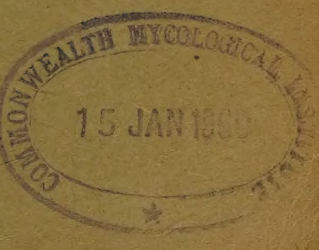
ANNUAL REPORT

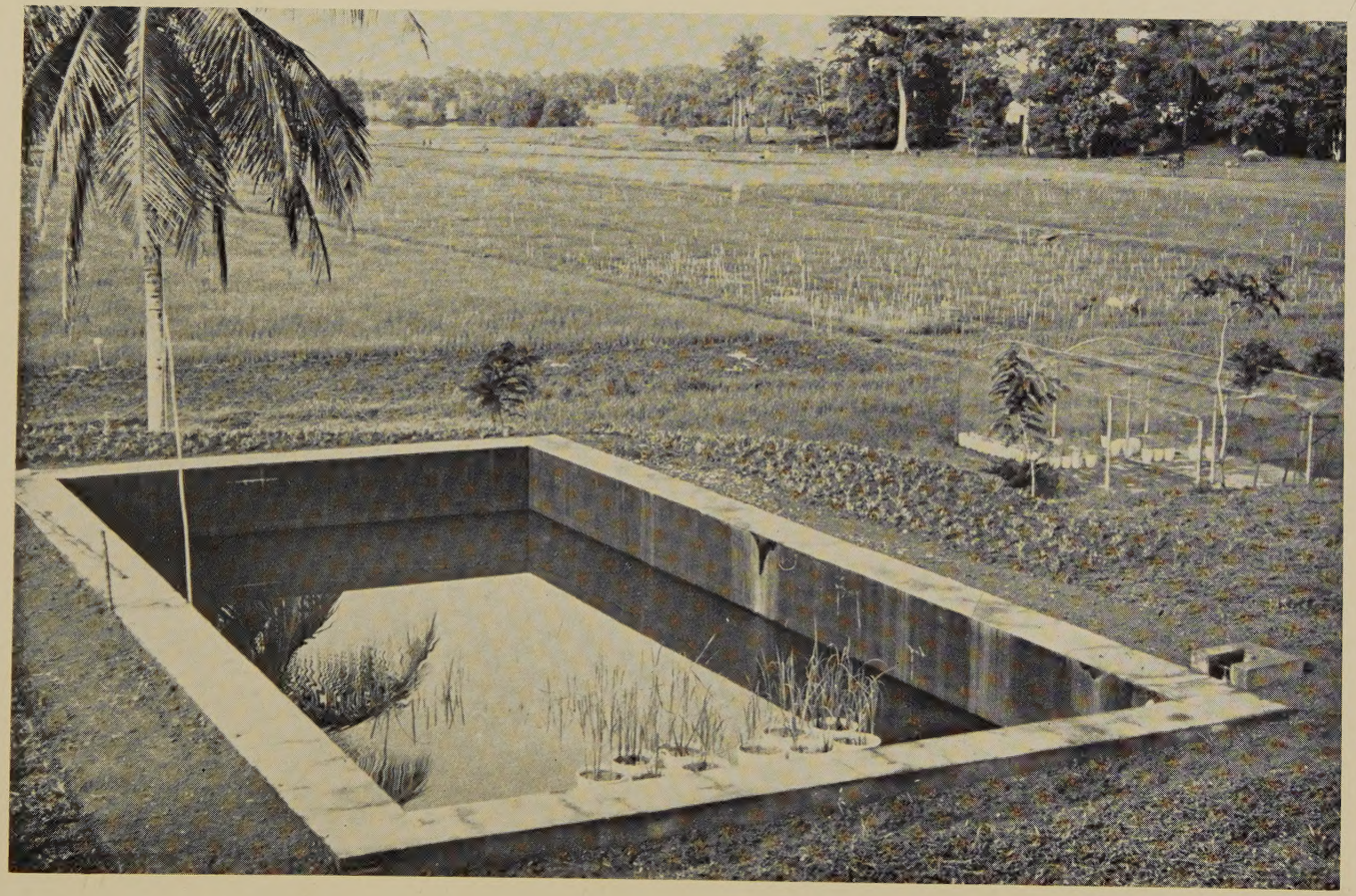
of the

WEST AFRICAN RICE RESEARCH STATION

1958







WEST AFRICAN RICE RESEARCH STATION

View overlooking part of the Experimental Farm showing the Deep-water Rice Tank and Plant Cage in the foreground.

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ADMINISTERING AUTHORITY

THE SIERRA LEONE GOVERNMENT

Director of Agriculture:

J. W. D. GOODBAN, O.B.E., M.A., DIP.AGRIC., A.I.C.T.A.

ADMINISTRATIVE AND PROFESSIONAL STAFF

At 31st March, 1959

Officer in Charge:

H. D. JORDAN, B.SC., A.R.C.S., A.I.C.T.A.

Botanists:

E. H. ROBERTS, B.SC., PH.D.

R. Q. CRAUFURD, B.SC.

A. J. CARPENTER, B.A., DIP.AGRIC.SCI.

Soil Chemists:

P. R. HESSE, B.SC., PH.D., F.R.I.C.

J. W. O. JEFFERY, B.SC.

Soil Microbiologist:

M. G. R. HART, B.SC., PH.D.

Station Management:

J. C. RIPPEY, B.AGRIC.

FOREWORD

The year 1958 under review marks a particularly important stage in the development of the West African Rice Research Station.

Not only has the station become fully staffed in its expanded form for the first time, but also, in December, a meeting of the Technical Sub-Committee, attended by representatives from Ghana, Nigeria and Sierra Leone, was held at Rokupr itself.

This meeting, together with the increasingly more frequent visits by Rice Research Station staff to the other West African territories, has done much to further the good relations already existing and to encourage all concerned in the vital work which remains to be done to improve rice production throughout the area.

Whilst much important work has already been accomplished, and the results applied in the contributing territories, Rokupr can now legitimately consider itself to have come of age and to be in a far stronger position to tackle the many other problems whose resolution in the immediate years ahead can make an outstanding contribution to the welfare and economy of the peoples of West Africa.

The help and encouragement given by all Governments and through the Colonial Development and Welfare Act, which is making this possible, is most gratefully acknowledged.

J. W. D. Goodban,
Director of Agriculture,
Sierra Leone.

INTRODUCTION

The Introduction in previous Annual Reports has been used for a brief summary of the history and inception of the West African Rice Research Station and its financing and administration. It is proposed this year to discuss the agricultural background to the Station's activities.

Rice has long been the staple food throughout that part of West Africa that stretches from Casamance in the north to the western Ivory Coast in the south—an area nearly 1,000 miles long and 300 to 400 miles broad at its greatest extent. This economy has, in the past, been largely based on upland rice cultivation, but since the last century there has been an increasing emphasis laid on the production of swamp rice—in particular in the mangrove littoral. In this part of West Africa therefore, rice is a crop of major importance. Whereas in other parts of West Africa rice cultivation has tended to be comparatively less important in the past, there has nevertheless, in more recent years, been a steady increase in consumption following a general increase in wealth of the population and increasing urbanization. This tendency for rice to replace other cereals and root crops in West African diets is very marked and is generally considered to be desirable from the nutritional point of view. All administrations have given rice production an important place in their development programmes and there has been, and continues to be, a very considerable increase in the amount of rice produced.

It is doubtful whether large scale schemes for rice growing under water control and irrigation in West Africa will prove economic at the present time, and the only two such schemes which have been established tend to confirm this doubt. Simple and inexpensive measures of amelioration of natural water conditions can, however, be of great value in certain areas. Despite this it is considered that at present the major part of rice growing must be under natural conditions and the policy of the Station is largely framed on this assumption. There are large and widespread areas of land in West Africa that are potentially useful for rice growing and are at present undeveloped, though development is rapidly taking place. These represent a wide range of conditions—the coastal mangrove swamps, the inland valley swamps of forest country and moistland depressions of savannah areas, and the seasonally flooded riverain flood plains which may suffer prolonged heavy flooding or briefer periods of deep and rapid submergence.

The present policy of the West African Rice Research Station is thus to produce rice varieties to suit natural water conditions rather than to investigate the amelioration of such conditions to suit the rice plant, and the improvement programme and the more fundamental physiological investigations are framed on this policy. The example may be quoted of the Southern deeply-flooded grasslands of Sierra Leone which have largely been brought into production with improved strains of floating rices from Rokupr, and the Sokoto valley of Northern Nigeria where present investigations indicate that these strains may prove suitable for replacement of the poor quality *Oryza glaberrima* varieties now grown. It is appreciated that simple water control measures may be necessary on some types of land and the programme of the Soil Science section at Rokupr is largely that of investigation of the soils of potential rice lands and their

behaviour under varying conditions. As an example of this may be mentioned the saline mangrove lands where measures instituted to improve water conditions for rice growing led to detrimental soil changes. Recent investigations have elucidated the reasons for these changes and it is hoped that the results of this work will provide a basis for more successful methods of reclamation.

It is confidently expected that the West African Rice Research Station, working on these lines, in close collaboration with agricultural and agricultural research organizations in the contributing territories, and in close contact with developments in rice growing throughout West Africa, will continue to play an increasingly important part in the general economic development of the whole area.

ADMINISTRATION

With the change in the financial year, which will in future run from 1st April to 31st March instead of on the calendar year as hitherto, it has been found convenient to change similarly the period for which the Administrative section of this report is written. The Research Sections will continue to be based on the crop year. The administrative details reported this year therefore cover the period 1st January, 1958 to 31st March, 1959.

STAFF

Administrative and Professional

Mr. H. D. Jordan, Officer-in-Charge, went on leave in early June and returned at the end of October.

Dr. P. R. Hesse, Soil Chemist, arrived in January, 1958 on transfer from the East African Agriculture and Forestry Research Organization, where he had been for the past eight years. He acted as Officer-in-Charge in the absence of Mr. Jordan on leave.

Dr. M. G. R. Hart, Soil Microbiologist, was on the station throughout the year.

Mr. J. W. O. Jeffery arrived at the beginning of January, 1959 on first appointment as Soil Chemist, and his arrival completes the establishment of research officers in the Soil Science section.

The arrival in late September of Mr. A. J. Carpenter to join Dr. E. H. Roberts and Mr. R. Q. Craufurd in the Botany section has meant that all three posts of Botanist are now filled. Dr. Roberts went on leave at the end of February, 1959, and Mr. Craufurd at the end of March.

Mrs. D. L. Roberts continued to work as Temporary Botanist until the end of February when her appointment ceased.

Mr. J. C. Rippey remained in charge of Station Management.

Clerical and Technical

The continued employment of some staff of lower qualifications on a temporary basis has ensured that sufficient clerical staff have been available, although it has inevitably thrown more work on the fully qualified clerical staff as well as on the Professional staff.

On the reconstitution of a Fisheries Research Unit under the Sierra Leone Government in January, 1958, the two Laboratory Assistants on temporary transfer left Rokupr, and only three remained for the six posts. Four more were engaged during the year but, of these, two were found unsuitable and one resigned. Vacancies for two still therefore remain.

The field staff position remains satisfactory.

Unestablished Staff and Labour

Laboratory Attendants, Farm Guards, artisans and minor employees remain at full strength. Recruitment to these grades causes little difficulty.

The labour force averaged 110 through the year.

PUBLICATIONS

The usual brief cyclostyled Quarterly Progress Reports continue to be issued, and the 1957 Annual Report was published during the year. The 1956 report was received from the printers at the beginning of the year and distributed.

Two further Periodic Scientific Reports were issued. The first of these (No. 8) deals with the use of arboricides for killing mangroves, and the second (No. 9) with tasting tests.

Bulletin No. 4, " The Scarcies Rice Areas of Sierra Leone " was also issued during the year, and consists of a series of reports on rice growing on the tidal mangrove land which fringes these two rivers.

One paper was published.

" Rice Destruction by Crabs." H. D. Jordan. World Crops, March, 1958;

and four more have been prepared and submitted for publication:

" Geotropic and Morphological Alterations in Rice Seedlings caused by Plant Growth Regulators." E. H. Roberts. Nature, April, 1959;

" Sulphur-oxidation in Tidal Mangrove Soils of Sierra Leone." M. G. R. Hart. Plant and Soil, Autumn, 1959;

" The Effects of Gamma BHC on the Growth of Rice Seedlings." E. H. Roberts. Empire Journal of Experimental Agriculture. January, 1960;

" Factors affecting the Viability of Cereal Seed. 1. The relationship between Temperature, Moisture and Half-viability Period." E. H. Roberts. Annals of Botany, Spring, 1960.

TOURING AND VISITS

While on leave, Mr. H. D. Jordan paid a brief visit to the headquarters of the Food and Agriculture Organization of the United Nations in Rome, and spent a few days at the Italian Rice Research Station at Vercelli. He also briefly visited the Pest Infestation Laboratory at Slough and the Herbarium at Kew.

Dr. M. G. R. Hart spent ten days in the Gambia in November, when he was able to see a wide range of rice lands and make certain observations on Gambian soils.

Dr. E. H. Roberts visited Nigeria in November, when he spent a few days at Badeggi and Ibadan and then three weeks touring the coastal areas of the Western and Eastern Regions.

Several visits were paid within Sierra Leone to varying types of rice lands.

VISITORS

Their Excellencies Sir Maurice Dorman, K.C.M.G., Governor of Sierra Leone, and Sir Edward Windley, K.C.M.G., Governor of the Gambia, honoured the station by a brief call in December, 1958.

The Honourables M. S. Mustapha, Minister of Finance, I. B. Kamara, Minister of Trade and Industry, and R. B. S. Coker, Minister without Portfolio in the Sierra Leone Government, paid brief visits during the year, as did also His Worship the Mayor of Freetown, Councillor L. Genet.

Mr. G. M. Roddan, Deputy Agricultural Adviser in the Colonial Office, spent a few days on the station in November, 1958, and Mr. P. A. Carter from the Colonial Office called in January, 1959. Professor D. T. Jack of Durham University and Mr. J. Inman of the Colonial Office visited Rokupr in March, 1959 in connexion with an economic survey of Sierra Leone. In April, Mr. F. N. Hepper of the Royal Botanic Gardens, Kew, spent a short period at Rokupr in the course of a collecting expedition to West Africa.

From further afield, visits were also received from Professor B. F. Johnston of Stanford University, California, in March, 1958, Mr. N. Heseltine of the Food and Agriculture Organization of the United Nations in May, and from Dr. and Mrs. Herklots of the Imperial College of Tropical Agriculture in Trinidad in February, 1959.

A meeting of the station Committee was held at Rokupr on 18th and 19th December under the chairmanship of Mr. L. G. Heptinstall, acting Chief Secretary, West African Inter-Territorial Secretariat. Mr. J. S. Annan, Permanent Secretary, and Dr. W. K. Agble, Plant Breeder, represented Ghana. Nigeria sent four representatives. Mr. D. J. Parkinson, Permanent Secretary, Mr. D. R. M. Haynes, Agricultural Engineer, Mr. J. H. Hinds, Senior Botanist, and Mr. D. R. E. Jackson, Principal Agricultural Officer, representing the Federation and the Northern, Western and Eastern Regions respectively. Mr. H. W. Friend, acting Permanent Secretary, and Mr. J. W. D. Goodban, Director of Agriculture, attended on behalf of the Sierra Leone Government. The station and laboratories were inspected and brief visits were made to the Great and Little Scarcies in addition to the meeting itself. Mr. Haynes and Mr. Jackson stayed for a few extra days.

Other visitors from West Africa included Mr. Dunlop, Soil Chemist in the Nigerian Federal Department of Agricultural Research, in February, 1958, and Mr. R. A. Bull and Dr. P. B. Tinker of the West African Institute for Oil Palm Research in November.

MANAGEMENT AND MAINTENANCE

BUILDINGS

Three new Professional Staff quarters were built during the year. The Irrigation and Drainage branch of the Sierra Leone Department of Agriculture undertook the construction of these in the early stages but owing to the pressing nature of their other work they were forced to hand over the uncompleted buildings which were finished by the station's own resources.

Other construction work was carried out solely by the station and included one block of four quarters for Farm Guards completed and a further block of two nearing completion by the end of the year.

A deep water tank has been built for testing the behaviour of rices under controlled water conditions. This tank has a stepped bottom, and on the lowest level a depth of ten feet of water can be obtained above soil level when rice is grown in pots.

The old mud-block rice store has been demolished and a new permanent building erected. When complete, one section of this will be air-conditioned in order to preserve the viability of seed.

The old office building has also been demolished and construction of a permanent store and minor office building on the site started.

Concrete sluices have been installed in the main farm bund. These will normally be left open, but it is wished to exclude tide water for brief periods to assist in efficient cultivation and planting of the farm.

A small room in the main laboratory building has been air-conditioned as an instrument room.

SERVICES

The trouble with dirty water again occurred in the dry season. Provision has been made for the installation of a small filter plant and it is hoped that in future the position will be much more satisfactory. There was a breakdown in supply in February and shortage of water for two weeks caused considerable inconvenience in the laboratories.

The electricity supply, which continues to be managed by the Sierra Leone Electricity Department, gave satisfactory service, though voltage and cycle fluctuations interrupted the use of some apparatus. It is hoped that a projected re-wiring of the laboratories, including the use of fused plugs, will assist in protecting costly apparatus from damage by surges.

VEHICLES AND MACHINERY

The Bedford lorry was involved in an accident at the beginning of the year and was out of action for several months. The Land Rover kept running throughout.

A new diesel-driven launch was received during the year and the old launch was transferred to the Sierra Leone Department of Agriculture. It is now stationed on the Little Scarcies river where it is available for the use of officers of the West African Rice Research Station as required.

The Ferguson tractor has been in constant use, both with the trailer for cartage of materials and, during the rainy season, with the gang mower. The use of this, together with that of two Hayter motor scythes, has led to a further decrease in the labour force and consequent economy.

The M.G.6 tractor and implements continue to give good service in ploughing the drier parts of the farm.

STATION UPKEEP

No major work was carried out during the year but routine upkeep of the station continued.

The Angola Oil Palm plantation continues to be of interest to officers from the West African Institute for Oil Palm Research and seed from individual trees is collected as a routine measure.

EXTENSION AREAS

The small area of riverain grassland at Mando was again used for trials and, in the deeper parts, for observations on floating rices.

Two small buildings were erected at the Sierra Leone Department of Agriculture's substation at Kontobe for use as Rest houses and stores. Increasing visits are being made by research officers from Rokupr to this seasonally flooded grassland and it is hoped to expand the investigations there, particularly the soil investigations.

WEATHER

There was again a severe dry season at the beginning of the year—only negligible quantities of rain falling in the first three months. April, May and June, however, had precipitations above average. The rains eased off in July and August, July in fact having a record low rainfall. For the rest of the year the rainfall was above average in each month, November rainfall being in fact a record high one. Although the graph of monthly rainfall again shows a double peak it is not very marked, and the general picture is of a prolonged rainy season with the period of greatest intensity much later than usual. The total rainfall for the year was above average. Other meteorological factors followed a normal pattern except where they were influenced by the rainfall. November thus had record low amounts

of sunshine and a record low average maximum temperature. Full meteorological records for Rokupr for the year are given in Appendix A.

AGRONOMY

General nursing and planting procedure continues to be based on the results of earlier agronomic experiments and none of such trials are now being carried out.

Spraying with a technical benzene hexachloride suspension against crabs was increased this year—regular fortnightly spraying of drains and bunds being carried out in the late dry season and additional spraying of experimental areas being done at planting time. As a result crab damage this year was negligible.

Farm yields as usual reflected the general yields of the area, which were very much better than in the previous season. In past reports a table of yields has been included but, as the area under experiments has now increased and as more frequent changes of variety are now made on the farm blocks still used for multiplication, it is thought that this no longer serves a useful purpose and it is omitted this year. The planting plan is similarly omitted. The highest yield recorded from rice grown on a field scale on blocks of about half an acre this year was 2,400 lbs. per acre of India pa lil 46. Two blocks of Ngasein 57, one of Toma 112 and two of Radin China 4 gave yields of over 1,800 lbs. per acre. On a smaller scale, yields of over 3,000 lbs. per acre were obtained on plots of about a twelfth of an acre.

Sughandi has been omitted from the varieties of which seed stocks are maintained and which were listed in the last report. The two newly released varieties, Faya and Radin China 4, were added to the list. A total of 380 bushels (of 60 lbs. weight) of seed was produced. Purity of this is of a high standard, and the Genetic Stock system, whereby multiplication is carried out in stages from single plants bagged annually, is now established as a routine measure.

ARBORICIDE AND HERBICIDE TRIALS

No further work with arboricides was carried out during the year but a preliminary attempt to examine the effectiveness of herbicides for weed control on flooded riverain grasslands was made.

2,4-D (2,4-dichloro-phenoxyacetic acid) and MCPA (2-methyl,4-chlorophenoxyacetic acid) as butyl esters at concentrations of $\frac{1}{2}$, 1 and 2 lbs. per acre (acid equivalent) were sprayed on plots arranged in a statistical layout at, and one week after, the sowing of rice seed. Observations showed a marked detrimental effect on germination and growth of the rice on all treated plots—the effect being greater with the post emergence treatment. Laboratory tests showed that at the concentrations used germination was inhibited. Observations made later in the year showed that while the effect on the rice was noticeable, particularly with the higher rates of application, the effect on the grass weeds—the major weeds on the area—was negligible. No further observations or records were therefore taken from the experiment.

BOTANICAL RESEARCH

The plant improvement programme, with its detailed recording and trials, has remained the most important part of the botanical work, but it has not only been possible to expand this work in 1958 but considerably to increase the investigations into physiological problems.

A number of new varieties, 52 in all, were received in time for sowing this year and were added to the observation collection. A list of these and their countries of origin is given in Appendix B. Eight of these, however, failed to germinate or failed in their early stages of growth. In addition the 33 floating varieties of *Oryza glaberrima* from Nigeria which failed last year were re-introduced and successfully grown under conditions of permanent standing water in one of the old experimental polders.

Two further swamp rices were collected in Sierra Leone and also added to the collection. Owing to rigorous discarding the collection was reduced in number this year to 401 varieties. Of these, 224 were grown in the larger sized plots for observation and 177 in the smaller sized plots for maintenance only, as described in the last report. Thirty varieties of upland rice were grown in the small upland collection.

Twelve floating rices were also grown under observation in small plots under more typical conditions on the station extension area at Mando.

Records of the characters of all new introductions were made and transferred to punched cards for filing.

Requests for rice samples continue to be received both from within and without West Africa, and the following numbers of rices were despatched during the year:

To Gambia	9 samples
To Ghana	5 samples
To Nigeria	1 sample
To Zanzibar	7 samples
To Mauritius	8 samples
To Phillipines	6 samples
To British Honduras	21 samples

Promising Varieties

The long narrow plots used for the most promising of recent introductions in the last two years have proved most successful, and the practice of growing varieties in this type of plot has been made standard. As there is differing fertility over the area used for these plots, the site of each individual variety is changed each year and its performance under at least three levels of fertility can therefore be assessed.

Yields were higher in general throughout the farm than in 1957 but only four varieties gave yields of over 3,000 lbs. per acre. One of these, Bong Sen Den (from South Viet Nam) is a newcomer to the series and of the other three, Sokotera (from Zanzibar) and Anak Didek and Nachin 11 (both from Malaya), the first two have shown consistently good yields while the last, though giving good yields in the years 1954-56, was only mediocre in 1957. Other rices which continue to give good, though not outstanding, yields are Radin China 4, Radin Siak 34 and Mayang Ebos 80 (all from Malaya), Pai Gazo and Gantang (both from North Borneo) and H.R.8 (from Hyderabad). Seri Raja (from Malaya) has now given good yields for two successive years after a poor start in 1956, and Ngasein Thidat C 24-102 (from Burma), which originally had been thought very promising, has now given a disappointing yield in two years out of five.

Five statistical yield trials were laid down at Rokupr. Two of these were repetitions of previous trials for the third successive year, and combined analysis for these three years has been carried out.

In a trial of early varieties, where the standard variety Lead 35 was used for comparison, there has been variation in the results from year to

year, but the general picture that has emerged is that the variety Faya (from Nyasaland) has given a highly significantly greater yield than the Lead selection in two years out of three and in the combined analysis, and that the varieties MLY B404 and MLY C401 (both from Burma) have consistently given significantly lower yields. Details of this experiment are given in Table 1. From these results and from general observations it has been decided to release the variety Faya for use by West African Ministries of Agriculture, and to cease all further work with MLY B404 and MLY C401. These varieties will now only be maintained in the collection.

TABLE 1

Yield trial of early varieties

Layout 6 × 6 Latin square.
Plots 15 × 13 feet planted at measured 6 inch spacing 2 plants per stand.
Area of plot harvested ·0033 acre.

Variety	*Mean yield in lbs./acre*			
	1956	1957	1958	*Variety mean*
Faya	1,804	1,677	2,187	1,889
Acheh Puteh	1,630	1,682	1,551	1,621
Maung Nyo B 24-92	1,645	1,715	1,453	1,604
Lead 35	1,744	1,186	1,749	1,560
MLY B404	1,484	1,411	1,390	1,428
MLY C401	1,485	1,194	1,094	1,258
Season mean	1,632	1,478	1,571	1,560
Critical difference (5%)	220	291	186	130
Critical difference (1%)		397	254	173
Coefficient of variation	11·2	16·3	9·9	12·6
Critical difference Seasons (5%)				92
Critical difference Interaction (5%)				351

In a trial of early maincrop varieties it was unfortunately found necessary to change the standard variety from Sughandi to B.G.79 after

TABLE 2

Yield trial of early maincrop varieties

Layout 6 × 6 Latin square.
Plots 11 × 11 feet planted at measured 6 inch spacing 2 plants per stand.
Area of plot harvested ·0019 acre.

Variety	*Mean yield in lbs./acre*			
	1956	1957	1958	*Variety mean*
Anak Didek	1,964	1,190	1,724	1,626
Radin China 4	1,819	1,341	1,513	1,558
Subang Intan 117	1,627	1,226	1,503	1,452
Radin Siak 34	1,805	1,119	1,423	1,449
Reyong 6	1,614	1,223	1,508	1,448
Standard	2,058	930	1,101	1,363
Season mean	1,815	1,172	1,461	1,483
Critical difference (5%)	253	342	353	173
Critical difference (1%)	346			230
Coefficient of variation	11·6	14·7	20·1	15·5
Critical difference Seasons (5%)				130
Critical difference Interaction (5%)				664

1956 owing to failure of the seed. Combined analysis has, however, been carried out for the three years and Anak Didek and Radin China 4 have given significantly higher yields than the standard. Details of this experiment are given in Table 2. Anak Didek shows a tendency to lodging and has not shown up so well in other experiments and a decision on this variety has been deferred, but Radin China 4 is now being released by the station.

A further yield trial of early maincrop varieties, in which Toma 112 and the early rice D 99 were included as standards, showed in 1957 a significantly higher yield by Parn A-191 (from Thailand) than either standard or any other variety. This year Parn has continued to give a significantly higher yield than D 99 though not than Toma. D 99 has in fact given a yield highly significantly lower than any other variety in the trial. Details of this experiment are given in Table 3.

TABLE 3

Yield trial of early maincrop varieties

Layout 7 × 7 Latin square.
Plots 12 × 12 feet planted at measured 6 inch spacing 2 plants per stand.
Area of plot harvested ·0023 acre.

Variety	*Mean yield in lbs./acre*
Toma 112	3,146
Parn A-191	2,952
Anak Didek	2,909
Radin Siak 34	2,722
Siam 9	2,578
Nachin 11	2,489
D 99	1,758
Critical difference (5%)	376
Critical difference (1%)	506
Coefficient of variation	13·0

A statistical yield trial of late maturing varieties was laid down this year. Two standard varieties were included in this trial, Kav. 12, an earlier reselection from the Madras rice Kavunginpoothala, and a local selection, India pa lil 46. Details of yield are given in Table 4. Gantang and Raminad (from the Phillipines) gave significantly higher yields than Kav. 12 and all four introduced varieties gave significantly higher yields than India pa lil 46.

TABLE 4

Yield trial of late varieties

Layout 6 × 6 Latin square.
Plots 15 × 15 feet planted at measured 6 inch spacing 2 plants per stand.
Area of plot harvested ·00388 acre.

Variety	*Mean yield in lbs./acre*
Gantang	3,437
Raminad	3,352
Pai Gazo	3,301
Seri Raja	3,142
Kav. 12	3,091
India pa lil 46	2,903
Critical difference (5%)	220
Critical difference (1%)	303
Coefficient of variation	5·7

One further trial of early rices was established this year at Rokupr. B.G.79 and Lead were included as standard varieties, and while B.G.79 gave a significantly higher yield than HM C 19 and Pindosein A 29-20 (both from Burma) as well as H.R.8, Lead only showed superiority to the last named, which in fact gave a yield significantly lower than any other variety in the trial. Details are given in Table 5.

TABLE 5

Yield trial of early varieties

Layout 7 × 7 Latin square.
Plots 12 × 12 feet planted at measured 6 inch spacing 1 plant per stand.
Area of plot harvested ·0023 acre.

Variety	*Mean yield in lbs./acre*
B.G. 79	3,605
Lead	3,473
Maung Nyo B 24-92	3,368
Haji Haroun	3,204
HM C 19	3,068
Pindosein A 29-20	3,068
H.R. 8	2,512
Critical difference (5%)	431
Critical difference (1%)	580
Coefficient of variation	12·4

A yield trial was again laid down on the station extension area at Mando but this showed no significant differences.

Assistance was once more given to the Sierra Leone Department of Agriculture in the laying down of a yield trial under mechanization on the central riverain flood plains of Sierra Leone. The trial repeated that carried out last year, six standard varieties and six promising varieties being included. Yields were better than in 1957 but not so good as yields

TABLE 6

Yield trial on riverain flood plains

Layout Randomized Block 4 replications.
Plots 220 yards × 11 feet 8 inches combine drilled at 50/60 lbs./acre seed and 200 lbs./acre superphosphate.
Area of plot harvested ·18 acre.

	Variety	*Mean yield in lbs./acre*
	Parn A-191	1,101
	Faya	766
	Pindosein A 29-20	707
S	India pa lil 46	659
S	D 114	655
	Haji Haroun	642
S	Panianala	620
	Nachin 11	601
S	Lead	584
	Radin Siak 34	584
S	Toma 112	565
S	Sughandi 57	459
	Critical difference (5%)	195
	Critical difference (1%)	261
	Coefficient of variation	20·4

S—Standard variety.

in a similar trial in 1956. India pa lil 46 was again the best of the standard varieties and the yields of this and of D114, which failed to germinate last year, were significantly higher than that of Sughandi 57. Very different results were, however, obtained from the promising varieties, those showing up the best last year being indifferent this year. Parn A-191, though not being outstanding last year, has this year given a yield highly significantly higher than any other rice in the trial. The yield of Faya is significantly higher than that of Toma 112 or Sughandi 57, and that of Pindosein A 29-20 (from Burma) is significantly higher than that of Sughandi. The results of this trial are shown in Table 6.

Milling Experiments

On receipt of the fan and heater it has now been possible satisfactorily to develop the artificial drier for small rice samples, and work on milling quality has been started with artificially dried grain. However, the conductivity method of moisture determination used at present necessitates storage of samples after drying in order that equilibrium may be reached. As a consequence of this it is not possible to follow closely the drying process and arrive at a pre-determined moisture content, and routine examination of the milling quality of the rices in the collection has therefore been postponed until a more satisfactory method of determining moisture content is available.

Examination has been started of the effect of field conditions on milling quality, in particular the effect of the alternate wetting and drying that rice receives during periods when the harmattan wind is blowing, and the effect of earlier harvesting. This work will be continued in future years under more controlled conditions as this year's work has shown that considerable diurnal variation in moisture content in unharvested paddy does occur, though due to the difficulties of moisture determination mentioned above it has not been possible to correlate this at present with milling quality.

Palatability and Cooking Quality

The relative preference of local householders for different varieties of rice was investigated by means of a tasting panel, and the main established varieties of rice and three promising varieties were examined in this way. Particular interest was attached to the inclusion of the variety Faya, which is now released from the station and which is reported to be a scented variety. A statistical layout was used with eleven persons in the panel, and at each of five tests each person was given three varieties, one of which was a standard used in every test, and asked to indicate which in their opinion was the best liked and which the least liked.

The results after statistical analysis are given in Table 7 and show the well established (and therefore presumably acceptable) variety Toma 112 at the bottom of the table, and that the established varieties Lead and Kav. 12 and the three promising varieties, including Faya, are significantly preferred to Toma 112. It can therefore be said that the newly released varieties Radin China 4 and Faya are not likely to be rejected by local Sierra Leone farmers on account of palatability.

Preliminary investigation of these same varieties by physical and chemical tests has been started to see whether preference can be correlated with the results from any of these tests. The amylose content of the rice grain, the increase in volume and weight on cooking and the cooking time have all been examined but further work is needed before any definite conclusions can be reached.

TABLE 7

Consumer preference for rice varieties

Variety	*Preference score on 0-10 scale*
Radin China 4	6·6
Lead (Standard)	6·3
Kav. 12	6·2
H.R. 8	5·6
Faya	5·2
Indo-China 53	4·6
India pa lil 46	4·1
Sughandi HM A 6	3·9
D 99	3·5
Bolo 108	3·4
B.G. 79	2·2
Toma 112	2·1
Critical difference (5%)	3·1
Critical difference (1%)	4·1

SELECTION OF IMPROVED RICES

With the increase in numbers of introduced varieties and more attention being paid to hybridization, the selection of improved types from local rices, which has in the past formed an important part of the improvement programme, is slowing down and this year no new selections were made. Observations were made on selections from previous years and brief notes on these are given below.

First Year Selections

Thirty-seven of the Ngasein 57 re-selections were discarded after examination of field characters and the remaining 63 retained.

Second Year Selections

Only three of the Panianala and one of the Meike selections were retained for further observation.

Third Year Selections

A further three selections of Kurulutuduwi b.13 were discarded, leaving three for future work.

Fourth Year Selections

Eight selections of Kema and five of Lath remain. These two varieties are reputed to have considerable tolerance to submergence and it is hoped to examine the selections for this character in the new deep water tank in the coming season.

Fifth Year Selections

Only two selections of the local floating rice Mbagboli remain, and these will now be compared with other floating varieties, both in field experiments and in the deep water tank.

HYBRIDIZATION

New Crosses

A number of crosses between four early rices, forming a diallel series, were made. The parents were the two established varieties Lead and

B.G.79 and two promising more recent introductions, Faya and H.R.8. These were crossed in all combinations with the intention of growing the F_1 offspring from all six crosses, together with the parents, in a replicated trial in 1959. Theoretical predictions worked out by Mather and Jinks suggest that information from such a trial can estimate combining ability, degrees of dominance and heterotic components in the crosses and enable the most promising parental combinations to be selected. Difficulty was experienced in making enough crosses using the hot flask technique. These crosses are to be repeated and several new ones attempted in 1959 using a variety of hybridization methods aimed at increasing the amount of F_1 seed available.

A further attempt was made to produce the inter-specific hybrid between *Oryza sativa* and *O. glaberrima* varieties, and some 25 putative hybrid seeds were obtained and will be sown in the 1959 season. Floating *O. glaberrima* rices are reputed to grow more vigorously than floating *O. sativa* ones, and it is hoped to examine this character in the coming season. The purpose of the inter-specific hybridization programme is to combine this vigour of growth with the higher yield and better grain type of the *O. sativa* rices.

Hybrids in the F_2 generation

Examination of the offspring of the 1956 crosses showed that two of these had been unsuccessful and that the seed produced was selfed seed. They were therefore discarded. Following on decided policy no line selection was made from the other two crosses but mass selection was made from each for bulk sowing in the F_3 generation. These crosses are:

X(56)2 Bolo 108 × Ngasein 57
X(56)3 Toma 112 × Indo China 53.

Hybrids in the F_5 generation

X(53)1 Indo China 53 × Indo China 24. One further line of this cross between two selections of floating rice was discarded after this year's observations and the remaining nine lines were harvested for multiplication and for observations and trials under deep water conditions.

Hybrids in the F_7 generation

Pedigree lines of the four 1951 crosses

X(51)1 Yēnti × DC39/15
X(51)4 Ngasein 57 × Tai Chu 65
X(51)5 Toma 112 × Ngasein 57
X(51)7 India pa lil 46 × Kav. 12

are now showing very little segregation, and after observation the most promising lines were harvested for multiplication and for future trials. It is of interest to note that certain lines of the cross X(51)4, which is a cross between *indica* and *japonica* varieties, showed considerable spikelet sterility, and re-selection from these lines has been made for further observation.

Natural Cross Fertilization

Examination of the plants grown from the seed from last year's experiments showed that these experiments had again given no satisfactory results. No further work is being carried out at present on the determination of the amount of natural cross fertilization.

Investigation of Components of Yield

One of the yield trials with early rices, the results from which are shown in an earlier section of this report, was planted with single plants, and this provided an opportunity of studying the components of yield of single plants within and between varieties. The tiller number, panicle weight, 100-grain weight and height of nine plants from each plot of the Latin square were measured. The results agreed with that of other workers in that no component or combination gave a more efficient measure of yield than yield itself. Some very useful information as to the amount of variance within pure lines was obtained which will help considerably in planning hybridization programmes.

PHYSIOLOGICAL WORK

Factors affecting the Duration of Rice Varieties

The integrating photometer which was set up at the end of 1957 gave records for most of the year but unfortunately ceased to function at the end of the season. It is hoped that the records obtained will, however, together with records from future years, give information on which it may be possible to base some conclusions.

With the co-operation of officers in other territories it was possible to carry out a successional sowing experiment in a number of places of similar and differing latitude. Four sowings were made of four different varieties. These were the photo-insensitive rice Tai Chu 65 and the early, medium duration and late photo-sensitive rices Lead, Radin China 4 and Wag Wag. Five sites were chosen, three of similar latitude and the other two in higher and lower latitudes respectively. These were:

Rokupr, Sierra Leone	9° 01′ N	West African Rice Research Station.
Nyankpala, Ghana	9° 25′ N	Ministry of Agriculture, Ghana.
Badeggi, Nigeria	9° 04′ N	Nigerian Federal Rice Research Station.
Sapu, Gambia	13° 29′ N	Gambia Rice Farm.
Nungua, Ghana	5° 40′ N	University College of Ghana.

Owing to differing conditions at these stations it was not possible to synchronize sowing dates, but the results have given some interesting indications. For the photo-sensitive rices there was at all stations a general reduction in maturation period (measured as the number of days from sowing to modal flowering plus 30 days) as sowings became successively later, but no marked effect of latitude on duration for any given sowing date is apparent. Table 8 gives the range at the various stations.

TABLE 8

Range of duration in days at five stations

Station	*Lead*	*Radin China* 4	*Wag Wag*	*First sowing*	*Last sowing*
Rokupr	189-135	237-173	274-204	25/4	31/7
Badeggi	182-138	248-171	296-214	30/4	23/7
Nyankpala	221-132	220-172	297-	1/4	30/7
Nungua	164-133	220-187	-	2/5	28/7
Sapu	207-147	235-174	279-218	23/4	24/6

Note.—The late variety Wag Wag failed at Nungua, and in the later sowings at Nyankpala, owing to unfavourable weather conditions.

With the photo-insensitive variety there were insufficient figures to draw any conclusions this year. At Nyankpala and Sapu, however, where the durations remained reasonably constant irrespective of sowing date, they were consistently shorter than at Rokupr, and it is thought that this may be due to other climatic factors which are under investigation. It is hoped to carry out further similar experiments in the coming year.

The successional sowing trial carried out in 1956 showed considerable effect from varying the sowing date on the number of panicles per plant, and the importance of planting at the right time to achieve maximum tillering was noted. Three statistical yield trials were laid down this year therefore to determine how sowing date affects yield. One of these, with the variety Radin China 4, failed to give a significant result. The other two, with varieties Lead and Faya, details of which are given in Tables 9 and 10, showed, however, that, for these varieties at least, sowing date has a significant effect on yield, sowings in June rather than in July or August giving the better yields. These experiments will be repeated in future years and it is not proposed at this stage to comment in more detail on significant differences in yields shown between specific sowing dates.

TABLE 9

Effect of sowing date on yield—Lead

Layout 6 × 6 Latin square.
Plots 15 × 15 feet planted at measured 6 inch spacing 2 plants per stand.
Area of plot harvested ·0038 acre.

Sowing date	*Mean yield in lbs./acre*
June 18th	3,316
June 4th	2,884
July 12th	2,830
July 2nd	2,540
July 30th	2,478
August 13th	2,457
Critical difference (5%)	427
Critical difference (1%)	584
Coefficient of variation	12·9

TABLE 10

Effect of sowing date on yield—Faya

Layout 6 × 6 Latin square.
Plots 15 × 15 feet planted at measured 6 inch spacing 2 plants per stand.
Area of plot harvested ·0038 acre.

Sowing date	*Mean yield in lbs./acre*
June 18th	3,388
June 4th	3,364
July 2nd	3,233
July 16th	2,637
July 30th	2,446
August 13th	2,006
Critical difference (5%)	432
Critical difference (1%)	592
Coefficient of variation	12·5

Water Relations of the Rice Plant

Investigations into the drought resistance of rice seedlings have continued. In addition to experiments designed to find out the periods at which rice seedlings are most susceptible to desiccation and the extent to which different varieties can withstand such desiccation, work has been started on the resistance of rice seedlings, both of swamp and upland varieties, to solutions of high osmotic pressure. It is thought that this technique may prove valuable in the investigation of drought resistance. At the present time, most attention has been paid to the perfecting of techniques and the full evaluation of the work awaits the completion of projected future experiments.

Dormancy and Viability of Rice Seed

The work briefly reported last year has been continued, and the effect of combining treatments with heat and with oxygen, which separately were both shown to reduce the dormancy period, has been examined. By this combination of treatments a practical method has been developed whereby dormancy of freshly harvested paddy can be broken completely in less than a week. It is expected that this will be of use in speeding up the breeding programme and developing photoperiod insensitive varieties for out of season cultivation. Further experiments are at present in progress and full details of this work will be given in a later report.

Work on the maintenance of viability in storage has also continued and is still in progress. In connexion with this, a critical examination of previous published work on the viability of cereal seed has been made. From a co-ordination of the experimental results from this previous work a simple mathematical relationship between temperature, moisture content and period of viability has been found. The resulting equation has the following form: $\log p = K_v - C_1m - C_2t$, where p = half viability period (period from harvest until germination has dropped to 50 per cent), m = moisture content of grain and t = temperature of storage. K_v, C_1 and C_2 are constants and values for these have been calculated for wheat from published work. There is evidence from the literature that these constants are the same for oats and barley, but published work on rice and experiments carried out at Rokupr give insufficient information at present to be able to say with certainty that rice obeys similar laws, though the available evidence strongly suggests that it does. Work in progress is designed to give further information on this point and to discover the limits for the application of the equation, as it is thought that changes may occur in the seeds outside the normal range of storage temperature and moisture content which will affect the relationship.

It has also been possible, from published work and work at Rokupr, to examine the distribution in time of the death points of individual seeds and to determine that this is approximately a normal distribution, and to obtain indications that, although micro-organisms may slightly accelerate the loss of viability at high moisture contents, the main factors causing loss of viability in cereals are intrinsic to the seed.

Hydroponics

Further work was started, on the receipt of apparatus, into the growing of rice plants in culture solutions. It is hoped by this method to be able to carry out investigations into the tolerance of different rice varieties to salt and to other mineral ions. This year has been devoted to perfecting a suitable technique and it has been found possible to develop a culture solution in which rice plants can be grown to maturity. It has also been found possible to produce a clone of material for study from a single rice

plant. The use of such clonal material should be of particular value when studying segregating rices.

DISEASES

The season was noteworthy for the severity of attack in the nurseries by *Piricularia oryzæ*. In addition to varieties known to be susceptible to attack, many varieties thought to be fairly resistant to this fungus showed the characteristic symptoms of scorch.

Close records were again kept on the incidence of this fungus in the varietal collection nurseries, and attack followed the same pattern as last year, there being two peaks of infection. Records of climatic factors were kept but it is proposed to continue observations for at least one further year before attempting to determine any correlation between these factors and severity of fungus attack.

Observations were also made on *Helminthosporium oryzæ* attack in the nurseries but, owing to the extreme difficulty of positively identifying this fungus in the early stages of attack, it was not possible to note any particular trend. This fungus rarely causes more than very minor damage to rice seedlings at Rokupr.

Ephelis pallida was again very scarce this season, only four panicles attacked by this fungus being seen. Three of these were on one plot of rice but the variety has not been recorded as it is thought that the plants attacked may have been rogues.

SOIL SCIENCE

Investigations have, up to the present, been concentrated on tidal mangrove soils, where problems had already arisen which indicated that a detailed knowledge of these soils and their behaviour on reclamation was essential before any further development could be carried out. A considerable amount of information on this subject has now been obtained and, with this as a basis, the emphasis of the work is moving from the laboratory into the field. It has therefore now been possible to pay attention to other types of rice soils and investigations on the soils of the seasonally flooded riverain flood plains of Sierra Leone have been started. These flood plains are being developed for rice growing under mechanization by the Sierra Leone Department of Agriculture and it is thought that their problems are similar in many respects to those of the flood plains that occur on most of the West African rivers, and particularly extensively in Nigeria.

INVESTIGATIONS INTO TIDAL MANGROVE SOILS

Tidal mangrove soils are being developed for rice cultivation throughout West Africa and are already of immense importance in the agricultural economies of Sierra Leone and the Gambia. In addition to the normal soil problems encountered in rice production these soils possess unusual characteristics by virtue of the influence of sea water, with which they are inundated to various extents. A feature of importance in the reclamation of permanently saline swamps, and possibly having considerable influence on the fertility of seasonally saline areas, is the high content of sulphur compounds in the soil. These substances normally exist in the reduced form, but are susceptible to oxidation when the soil is aerated. Complete oxidation of the sulphur compounds in the soil results in the establishment of extremely acid conditions which may prevent the growth of rice completely. This situation may occur in permanently saline swamps which are empoldered to prevent the ingress of sea water. Partial oxidation,

which occurs in tidal rice soils during the dry season, also causes an increase in the acidity of the soil, but such soils do not become intensely acid and a return to normal conditions occurs at the beginning of the rainy season, when rice is transplanted.

Sulphur-Oxidation

Microbiological work has been based on the assumption that a knowledge of the mechanisms of sulphur-oxidation and acid-formation in these soils would be necessary in the formulation of techniques for the economic reclamation of permanently saline areas. It is hoped that it will later be possible to link this information with studies on the influence of soil sulphur changes on the fertility of the cultivated rice soils.

The activity of *Thiobacillus thio-oxidans* in the oxidation of elemental sulphur in mangrove soils has been mentioned in a previous annual report. A detailed study has now been made of the oxidation of the various fractions of the soil sulphur reserves and the main points of interest may be summarized as follows:

(*a*) Ferrous sulphide and free sulphide.—These are not present in large amounts in the tidal soils studied and may rapidly be oxidized chemically with the formation of elemental sulphur. Observations made on empoldering schemes suggest that initial accumulation of sulphur from sea water occurs as sulphide in association with freshly decomposing organic matter.

(*b*) Elemental sulphur.—This occurs in large concentrations and is available for rapid oxidation to sulphuric acid by the bacterium *Thiobacillus thio-oxidans*. This organism has been found to be present in large numbers in tidal rice soils, even under waterlogged conditions, and becomes extremely active when the soil is allowed to dry and aerobic conditions are established. It is only necessary for such conditions to be established in the soil by a reduction of its moisture content for rapid sulphur-oxidation to occur with the formation of quantities of sulphuric acid and the consequent fall in the pH value of the soil to about 2·8. The activity of the organism has been examined at various stages in the oxidation process and it has been possible to obtain information on soil factors affecting its activity. This information has helped in suggesting explanations for hitherto conflicting results on the effects of lime on sulphur-oxidation reported by investigators in other countries. It is thought that the results will also help in making the best use of liming material in the neutralization of some acid soils.

(*c*) Polysulphides, possibly pyrites.—These also occur in large concentrations but appear to be stable to oxidation when the soil pH value is kept above 3·0. The results so far obtained suggest that the oxidation of pyrites in mangrove soils is not a bacterial action but probably occurs as a result of chemical oxidation by ferric ions released in soluble form at low pH values. This mechanism has been postulated by investigators of acid mine-water problems in the United States of America. Whether the oxidation of the iron is mainly a chemical or a bacterial process has not yet been determined in the mangrove soils, though it has been established as mainly bacterial in the acid mine-waters. Preliminary investigations in mangrove soils have shown that iron-oxidation in soil perfusion columns is sensitive to sodium azide. This indicates that the process is likely to be a biological one. In addition, cultures of iron-oxidizing bacteria are easily obtained from the soil. The part played by these organisms in iron-oxidation in the soil and their relationship to sulphur-oxidation and acid-formation is now being investigated.

A series of soil analyses was carried out in an attempt to discover the source of the variability which occurred in estimations of the total

oxidizable sulphur content of the soils. It was found that this variability was mainly due to the localized accumulation of sulphur in association with dead blackened wood. This wood may have been the remains of the mangrove from which the land was originally cleared, but later analyses showed that even old palm nut shells found in the soil had served as sites for the accumulation of large quantities of sulphur, and it was concluded that accumulation of sulphur in the soil had occurred in association with decaying organic material. This was to be expected; as mentioned earlier, monosulphide is often found in freshly cleared swamps in association with freshly decomposed mangrove remains, though there is no certainty that the sulphur comes from the tidal water rather than from the organic sulphur of the plant remains. More detailed examination of the sulphur accumulations showed, however, that the majority of the sulphur present was in the form of polysulphide and it seems likely that this was formed from the original deposit of monosulphide sulphur which occurred when the material was newly decomposed and the conditions reducing. The way in which polysulphides are formed in soil is not yet known for certain. Classical ideas were that the process was a very slow one, but recent work in the Netherlands has demonstrated that they may be formed rapidly in freshly suspended marine detritus under aerobic conditions. The age of the deposits referred to above is not known. It is hoped to investigate the process of pyrites formation in mangrove soils in more detail.

(*d*) Organic sulphur.—This has not been specifically studied, but the rapid rate at which sulphate is formed from the soil sulphur reserves tends to rule out the possibility of it being important for the present considerations.

The work is not yet at a sufficiently advanced stage for practical results to be forthcoming, but it is thought that the information obtained on pyrites oxidation might be of practical significance. The rate at which pyrites was found to be oxidized at normal soil reactions was very slow or negligible compared with the rate at which elemental sulphur was oxidized. At present it is not known what soil conditions favour the formation of these two substances, but should it be possible to establish soil conditions which would favour pyrites-formation rather than that of monosulphide or elemental sulphur it might be possible to limit sulphur-oxidation and thus avoid the establishment of conditions too acid for rice cultivation. Cursory observations suggest that soils which are higher and better drained are more likely to be pyritic than sulphidic or sulphuritic, and it is hoped that application of suitable drainage conditions to sulphidic soils before they are empoldered might encourage pyrites-formation and thus enable the elimination of the soil sulphur accumulations over a period of several years. It has been shown by workers in the Netherlands that, even under normal arable conditions, pyrites can remain in the soil in the un-oxidized condition for many years, so given suitable conditions and a detailed knowledge of the ways in which pyrites may be formed and oxidized the solution suggested above may be practicable.

When the problem of high soil acidities was originally encountered in Sierra Leone, it was quickly noticed that certain swamps were more suitable for empoldering than others. Observations made on the vegetation of the various swamps showed that a reasonably good correlation could often be observed between the vegetation of swamps and their suitability for empoldering. Swamps cleared from *Rhizophora* mangrove invariably became acid, whereas those cleared from *Avicennia* mangrove could often be empoldered with safety. In view of what has been said above on the distinction between pyritic and sulphidic soils, it is likely that *Avicennia* soils, which are usually higher and more permeable, can be classified as predominantly pyritic whereas *Rhizophora* soils, which are invariably

waterlogged and impermeable, might be termed sulphuritic. It yet remains to obtain experimental proof of this idea.

Decomposition of Organic Matter

As very little is known about the relationships existing between mangrove vegetation and fertility of the soil, a general investigation of this has been begun. This year has seen the start of a series of experiments designed to investigate the organic matter status of the coastal swamps and the factors affecting the decomposition of such organic matter. The site chosen is a swamp near Freetown which will also be used for future experimental reclamation schemes. It has the added advantage of adjoining a similar piece of land which was reclaimed fifteen years ago and has borne rice crops for four years, and which thus forms a useful site for comparison. The mangrove vegetation consists of a mixed stand of *Rhizophora racemosa* and *Avicennia nitida*. Two main kinds of soil are present, a fibrous sulphidic mud under the mangrove, and a silty non-fibrous mud bordering the numerous small creeks which intersect the area.

A profile analysis of the latter kind of soil has shown that the silty mud has a fairly uniform composition to a depth of four feet when it sharply alters in character and for the rest of the profile resembles the black fibrous mud. This sharp change of properties at four feet is illustrated by the following comparison of averaged analytical data for the topsoil and the subsoil. pH value 6·3 : 4·9, percentage carbon 3·6 : 11·9, carbon-nitrogen ratio 16 : 64, total sulphur in parts per million 2,115 : 72,114, total phosphorus in parts per million 834 : 250.

Incubation experiments have so far been confined to the topsoil and have been carried out in order to determine the rate of mineralization of carbon, nitrogen, phosphorus and sulphur. The freshly collected mud incubated for ninety days at 32°C. and at its natural field moisture content at low tide (48·8 per cent) gave the following results: in 100 grams (oven dry basis) of mud, 0·069 grams organic carbon, 0·004 grams organic nitrogen and no organic sulphur were oxidized. This represents a very slow rate of mineralization, a fact confirmed by respirometric experiments. The slow rate of decomposition is probably due to the high moisture content, but as 50 per cent represents the lowest moisture content that will normally occur in the field, the figures obtained are the maximum that can be expected.

In order to predict the course of mineralization of organic matter in the silty mud if the land were empoldered, i.e.—subjected to a seasonal drying out of the topsoil, the experiments were repeated on mud which was air-dried and re-moistened to 50 per cent moisture content. Re-moistening after air-drying resulted in an initial flush in the rate of decomposition—a common phenomenon in soils—but which lasted for only 48 hours after which time the decomposition resumed the steady slow rate of undried mud. A second drying of the mud produced a much smaller flush of decomposition on re-moistening, and further dryings gave even smaller flushes. The mud was dried four times in all, the total incubation period being sixty days. In this time in 100 grams (oven dry basis) of mud, 0·068 grams carbon, 0·015 grams nitrogen and 0·048 grams sulphur were oxidized. Thus air-drying and re-moistening, while hardly affecting the total carbon mineralization, resulted in a considerable increase in nitrogen and sulphur mineralization over that in undried mud. The large increase in sulphate was not in this case due entirely to oxidation of sulphide, and the nitrogen mineralized appeared mainly in the ammonium form. Re-moistening after oven-drying the mud caused very much bigger flushes of decomposition, but these too fell off rapidly in magnitude on repetition.

One further experiment with the silty mud has been completed; this is on the effect on the rate of decomposition of leaching the mud free from excess salts. The fresh mud contained 7 per cent (dry weight) of chloride, but its removal by leaching caused no difference in the rate of organic matter decomposition.

The sulphidic fibrous mud is more typical of coastal mangrove swamps and its investigation will be more detailed than that of the silty mud. Certain of its properties have been previously described, particular emphasis having been laid on the fact that drying the mud results in acidity and oxidation of sulphur compounds to sulphate. It has been concluded that fibrous mangrove soils on drying will produce conditions too acid for rice growth, that such soils are generally associated with *Rhizophora racemosa* and that the fibrous nature of the soil is probably due to undecomposed mangrove roots.

The field moisture content at low tide (60 per cent) is higher than that for the silty mud due to the water holding capacity of the fibres. On incubation at this moisture content the mud decomposed at a higher rate than did the silty mud, but as the experiment is unfinished no analytical data are yet available. Respirometric experiments, using the fibrous material from the mud, have shown that this material decomposes at a far higher rate than does the mud, although if the data for the decomposition of the mud are plotted on the basis of its organic matter or fibre content then the curves showing progress of decomposition are practically identical with that for fibre alone. The oxidation of carbon and the oxygen uptake of the mud are thus almost entirely accounted for by its fibre content.

In continuation of this experiment, freshly collected roots from the living mangrove (*R. racemosa*) were analysed and incubated. The roots divide in a complex manner when in the soil, but eventually the thick fleshy roots terminate in clusters of fibrous rootlets; for the purposes of analysis these rootlets were distinguished from the fleshy roots. It was found that the soft fleshy roots decompose rapidly on aerobic incubation whereas the decomposition of the fibrous rootlets follows the same pattern as that of the fibrous material isolated from the soil. Thus, though insufficient analytical data are yet to hand for certainty, the experiments indicate that the fibrous rootlets of *R. racemosa* are the source of the accumulated fibre in the mud. Furthermore the experiments indicate that, given the right conditions, this fibrous material will in fact decompose; this fact will be of importance when developing reclamation techniques.

In a further experiment, mud was allowed to dry for various periods of time so as to give a series of samples with a range of moisture contents from field moisture at low tide (60 per cent) to completely air-dry. These muds were then incubated in the respirometer, as were other samples to which creek water had been added to give 80 per cent moisture and the waterlogged conditions of one inch of standing water. The results showed that the optimum moisture content for oxygen uptake and carbon oxidation is 50 per cent and that the field moisture content at low tide is almost as favourable. During the period of decomposition (15 days) the mud under natural drained conditions oxidized 35 parts per million nitrogen and at least 1,500 parts per million organic or elemental sulphur. Under the much drier condition of 10 per cent moisture only 300 parts per million sulphur were oxidized although the amount of nitrogen was almost as great at 26 parts per million.

Further experiments dealing with decomposition under waterlogged, anaerobic and tidal conditions, and the effect of various mechanical and fertilization treatments, are in progress.

" Kumo " Soils of the Gambia

A visit was made to the Gambia to examine certain toxic soils occurring on the broad river flood plain of the Gambia river on the landward side of the mangrove zone. These soils, locally known as " kumo " soils, are never flooded by tidal water and are part of the " banto-faro " area which is a traditional rice producing area. They are confined to those reaches of the river which are saline at some time of the year, and it was thought that their lack of fertility might be related to that of empoldered mangrove soils.

Visits were made to a number of sites and representative surface soil samples were examined at Rokupr. Although the samples were taken at the end of the growing season, most had a high salinity—sufficient to account for the lack of plant growth on the sites. In addition the soils had fairly low pH values (about 4·0) and high sulphate contents. However, the acidity of the soil at planting time could be expected to be less than this, and it is not considered that soil acidity is likely to be an important factor in the toxicity of " kumo " soils.

There seems little doubt that this type of land was once tidal and has been cut off from tidal action at least partly by the silting of creeks, which process is still going on and leading to reduction in rice yields in marginal areas. Re-establishment of tidal conditions should eliminate " kumo " areas irrespective of whether acidity or salinity is the more important factor in their occurrence. A system of channels leading into creeks would serve this purpose should the tidal rise and fall be adequate, or failing this would assist in the removal of stagnant water and dissolved salts.

INVESTIGATIONS INTO INLAND RICE SOILS

As part of a general scheme for improving rice growth on the inland seasonal swamps, the soil from one such site at Kontobe has been examined. A sampling site for preliminary work was chosen in a particularly infertile part of the flood plain, which also happens to be more deeply flooded during the wet season. Soil pits in the dry season showed a grey dusty topsoil overlying a bleached horizon which in its turn covered a very deep deposit of ironstone. The ironstone was conspicuous by the absence of any signs of manganese deposition, an observation which ties in with the findings of the Sierra Leone Agricultural Chemist whose pot tests showed a manganese deficiency.

Analysis of samples showed the following main points. The soils of all three horizons were acidic, having pH values of about 4·0; sulphate occurred, however, in the ironstone layer only. The topsoils were very sandy (60 per cent sand), and the clay present (8 per cent) was kaolinitic. The base exchange capacity of the soil was under 10 milli-equivalents per cent, implying that only small quantities of applied fertilizers can be fixed. The available phosphorus was negligible, which explains why such beneficial effects have been found on these soils from superphosphate dressings. The analyses confirmed a very low manganese content, about 15 parts per million, and furthermore showed that the upper layers of soil are poor in iron.

A series of analyses made from February to September showed that as the ground became wetter and the groundwaters rose, so did sulphate appear in the upper layers of the soil and decrease in the ironstone layer. This observation suggests the possibility of future sulphide toxicity, which could come about by transference of sulphate from the ironstone to the topsoils, its subsequent reduction to sulphide when deeply flooded, and its non-fixation because of the absence of iron or manganese. This has yet to be investigated, but a laboratory experiment has proved that small

quantities of hydrogen sulphide introduced into these topsoils will kill rice seedlings and that this is completely prevented by adding iron compounds. It is perhaps significant that rice growth was observed to be better on patches where the ironstone layer had broken through onto the surface of the ground.

Respirometric experiments made on the flood plain soils have shown that a large flush of humus decomposition occurs during the first 24-36 hours of rain after the dry season. During this period 0·1 grams carbon, 0·003 grams nitrogen and 0·001 grams phosphorus were oxidized per 100 grams soil but, owing to the kaolinitic nature of the clay present, the very low base exchange capacity and the continued rain, most of these released nutrients will be lost to the crop.

ANCILLARY INVESTIGATIONS

River Water Analyses

Analyses of Great Scarcies river water for chloride and sulphate content were carried out during the dry seasons of 1957 and 1958. It was reported in 1957 that a change in the ratio of chloride to sulphate in the water occurred during the dry season. This was the result of a reduced sulphate concentration and was interpreted as indicating that absorption of sulphate was occurring during the inundation of the rice lands with salt water. Similar results had been obtained previously by the West African Fisheries Research Institute from work on the Freetown river. Results obtained during 1958 have not confirmed the effect, however, and it has not been possible to demonstrate sulphate absorption from saline solutions using samples of soil at various pH values from different sites on the river at different times of the year. The time of the year at which sulphate accumulation occurs thus remains uncertain.

The analyses have given information on the way in which salinity fluctuations occur in the river, and it should in future be possible to predict the approximate salt concentration likely to be reached in the river water at any time of the year at particular sites. This information may later be of use in establishing trials of salt-tolerant rice varieties.

All the sites at which samples were taken showed a characteristic pattern of changes in concentration of salts. During the dry season the increase in salt concentration at a particular site followed a sigmoid curve and the maximum salt concentration was not reached for about four months after the increase had begun. On the other hand, the decrease which occurred at the onset of the rainy season was extremely rapid, and acceptable levels for rice cultivation were reached in highly saline reaches of the river within one month of the decrease beginning. This decrease was so rapid that the time at which planting could be safely begun would vary very little over the saline reaches of the river. The length of the salt-free period, which is of importance in determining the duration of the rice crop or the possibility of planting rice at all, is influenced to a greater extent by the rate at which the salt enters the river than the rate at which it leaves. It is suggested that in similar work of this kind it would be more important to obtain information about salt concentrations at harvest time, when salt damage is likely to occur, than at planting time, when the best time for planting can be determined accurately by the use of test plots as is done on the Scarcies in Sierra Leone.

Rain Water Analyses

As a possible means of reclaiming saline land for rice cultivation is its empoldering and subsequent leaching by rain, it was thought advisable to investigate the composition of the rain water. Consequently rain water

was collected at Rokupr throughout the season and analysed for chloride, sulphate, nitrate and ammonia. The results were unexpected, showing that in spite of the proximity of the sea and the prevalence of chloride-containing muds the rain contained no chloride at all. On the other hand the rain brought down large quantities of inorganic nitrogen and sulphate sulphur. Other analyses showed that very little calcium or phosphorus was deposited. Particularly in view of the unexpected results, further analyses are being carried out in the coming season, both of rain water collected at Rokupr and at other sites in Sierra Leone.

The rain water dripping from mangrove trees was expected to differ in its mineral content from the rain falling direct to earth and an attempt was made to collect and analyse such drips. Unfortunately only one sample was obtained as on all other attempts the apparatus was stolen. The analysis of this one sample confirmed that a considerable amount of soluble matter was being returned from the leaves to the soil.

APPENDIX A

METEOROLOGICAL RECORDS ROKUPR—1958

	Jan.	*Feb.*	*March*	*April*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year*
Rainfall	0·21	0·02	0·27	5·60	10·93	15·44	12·20	18·39	24·48	16·02	16·93	2·12	122·61
(20 year average)	(0·13)	(0·05)	(0·42)	(1·86)	(6·80)	(14·18)	(23·23)	(29·38)	(18·00)	(15·09)	(5·52)	(0·66)	(115·32)
Sunshine	244·8	224·0	235·9	184·0	165·3	137·7	78·4	39·5	115·4	176·3	144·8	220·4	1966·5
(15 year average)	(251·0)	(228·8)	(241·3)	(203·7)	(193·5)	(160·0)	(105·9)	(63·3)	(128·0)	(189·0)	(199·5)	(224·4)	(2188·5)
Mean Maximum Temperature	91·2	93;0	93·4	93·3	89·1	86·1	82·7	81·4	85·3	88·0	86·7	88·2	88·2
(20 year average)	(90·9)	(92·8)	(93·0)	(92·7)	(90·8)	(87·7)	(83·8)	(81·9)	(85·4)	(88·0)	(88·7)	(89·1)	(88·6)
Absolute Maximum Temperature	95	99	97	97	94	90	87	87	91	90	92	91	99
(20 year record)	(102)	(101)	(102)	(103)	(101)	(99)	(98)	(91)	(99)	(96)	(99)	(97)	(103)
Mean Minimum Temperature	71·5	72·5	72·5	74·6	73·5	72·5	72·0	72·0	72·1	70·9	71·9	69·7	72·1
(20 year average)	(68·3)	(69·7)	(71·6)	(73·0)	(73·5)	(72·4)	(72·1)	(72·0)	(72·3)	(71·7)	(71·8)	(69·5)	(71·5)
Absolute Minimum Temperature	64	69	67	70	69	68	69	67	69	68	69	60	60
(20 year record)	(50)	(60)	(62)	(65)	(69)	(63)	(60)	(67)	(68)	(68)	(63)	(53)	(50)
Mean Relative Humidity a.m.	89	88	—	82	87	91	90	91	91	89	91	86	88
(10 year average)	(88)	(87)	(84)	(82)	(84)	(89)	(92)	(93)	(92)	(89)	(89)	(88)	(88)
Maximum Relative Humidity a.m.	96	97	—	92	100	95	97	100	100	96	100	97	100
(10 year record)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)
Mean Relative Humidity p.m.	55	51	—	60	70	77	82	83	80	71	71	59	63
(10 year average)	(53)	(48)	(52)	(54)	(65)	(73)	(81)	(83)	(80)	(71)	(68)	(57)	(65)
Minimum Relative Humidity p.m.	29	24	—	42	56	59	62	64	58	61	37	30	24
(10 year record)	(16)	(14)	(23)	(31)	(31)	(54)	(59)	(53)	(51)	(41)	(37)	(10)	(10)

Rainfall in inches. Sunshine in hours. Temperature in degrees Fahrenheit. Relative Humidity as percentages. Morning readings taken at 09.00 hours. Afternoon readings taken at 15.00 hours. Bracketed figures are averages and records. No reliable Relative Humidity figures for March.

APPENDIX B

RICES INTRODUCED—1958

From India

Jirasar 280	ex Bombay
Kamod 118	ex Bombay
Pankhari 203	ex Bombay
Ketan Serang 1200	ex Bombay
Kolappala	ex Kerala
(**via Gambia**)	
Vellaikar Adt. 14	ex Madras
Velai Kuruvai Adt. 18	ex Madras
Co. 13	ex Madras
Co. 18	ex Madras
Thekkan Cheera Ptb. 10	ex Madras
Jhona 349	ex Punjab
Lal Nakanda 41	ex Punjab
Sanna Swarnavari TKM 6	

From Thailand

Bahng Pra
Khao Poodaht
Khao Tod Lawng
Nahng Mon
Nahng Tahni
Nam Dawk Mai
Puang Ngern

From Burma

Bilat Ngasein C 30-32
Kayangya D 402
Taungdi B 30-9

From Ceylon

M-302 × Mas M-24 (1900)
M-302 × Mas M-24 (1926)
M-302 × Mas M-24 (1949)
CH-18 × Mas M-24 (2126)
V 1 (28061) × Mas M-24 (800)
Pachchaiperumal 2462/11

From Malaya

Acheh Puteh
(**via Ghana**)
Jerum Perak
Mayang Legor

From Indo China (**via Guinea**)
Neang Champa
Neang Rei

From Formosa

Kaohsing (Takao) 27
Taichung (Taichu) 122

From Phillipines

Azucena
Intan
Kinandang Puti
Nagdami
Nagsanaya
Palawan
Peta
Pinulot
Tjahaja
Tjere Mas

From Madagascar

Madagascar 1300
Madagascar 1303

From French Sudan

Kassaba Kourouni

From Guinea

Indochine A
Indochine B
Indochine Blanc

From Peru

Minagra No. 1